Investigation of superconductor/magnet hybrids and superconducting thin films by isotope-specific scattering methods

Margriet J. Van Bael[1], Sebastien Couet[2], Maarten Trekels[2], Kelly Houben[1], Claire Petermann[2], Rudolph Rüffer[3], Michael Hu[4], André Vantomme[2], Kristiaan Temst[2]

[1]Laboratory of Solid State Physics and Magnetism, KU Leuven, Belgium
[2]Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium
[3]European Synchrotron Radiation Facility, Grenoble, France
[4]Advanced Photon Source, Argonne National Laboratory, Argonne, Illinois, USA

Hybrid magnetic/superconductor systems attract a lot of interest due to the proximity effects at the superconductor/ferromagnet (S/F) interface or the interactions between magnetic nanostructures and quantized flux lines in a superconducting film. In most studies, the influence of the magnet on the superconductor is considered, while the reverse, the influence of the superconductor on the magnet, is much less investigated. Moreover, it has always remained a challenge to probe the magnetization inside the superconductor, especially in S/F hybrids.

Here we use an isotope-sensitive technique to selectively probe the magnetic constituent of S/F hybrids. The proposed method is based on nuclear resonant scattering (NRS) of synchrotron radiation and probes the local hyperfine field at the nucleus of specific Mössbauer isotopes such as ^{57}Fe. We studied Nb/Fe/Nb trilayers to demonstrate that ultrathin ^{57}Fe layers can be used to probe the magnetization *inside* a superconducting film. It is found that entering the superconducting state leads to a change in the Fe hyperfine field angle below T_c. This proof of principle experiment opens opportunities, particularly for the study of ferromagnet/superconductor hybrids. As a demonstration, the NRS technique was used to probe the possible *influence of the superconductor on the magnet* in a S/F system with nanoscale Fe islands burried under a Nb layer. Clear indications are observed of a superconductivity-induced magnetic reorientation of the Fe nano-islands.

Significant advances in nuclear resonant scattering have also allowed access to isotopes other than ^{57}Fe. In a second example we discuss recent work where we applied nuclear inelastic scattering on the resonance of ^{119}Sn to determine the phonon density of states in Nb_3Sn superconducting films grown by co-evaporation of Nb and ^{119}Sn. As the films become thinner, we observe a softening of the phonon modes. Our experimental results are correlated with the thickness dependence of the critical temperature and are compared to ab-initio calculations.